Effect of Sawdust Additive on the Properties of Clay

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Abstract

This contribution reports on the determination of effect of sawdust additive on the properties of clay which include bulk density, porosity and permeability, shrinkage on firing, cold compressive strength, refractoriness, thermal shock resistance and thermal conductivity. The clay sample was collected from a deposit in Minna, Nigeria. It was cleaned, soaked, dried, crushed and sieved then moulded to some definite shapes such as cylindrical, rectangular and circular depending on the type of test carried out on the various clay samples. Various percentages of sawdust from mahogany wood were added to the clay sample and moulded to the same definite shapes as stated above in the second phase. Various experimental methods were later used to determine the variation of clay properties with addition of sawdust. Results obtained show that while some properties were improved with addition of sawdust, others did not.

Keywords: *Bulk density, porosity, permeability, refractoriness, thermal shock.*

Introduction

Clay is regarded by an ordinary person as a kind of natural earth. When mixed with water; it becomes plastic and mouldable and becomes hard again on drying and firing.

Clay is a very fine grained, unconsolidated rock matter, which is plastic when wet, but becomes hard and stony when heated. It has its origin in natural processes, mostly complex weathering, transported and deposited by sedimentation within geological periods. Clay is composed of silica (SiO_2), Alumina (Al_2O_3) and water (H_2O) plus appreciable concentration of oxides of iron, alkali and alkaline earth, and contains groups of crystalline substances known as clay minerals such as quartz, feldspar and mica (Folaranmi 2009). Clay is used in various fields such as geology, chemistry, soil science, engineering and ceramic technology.

The objective of this contribution is to determine the effect of sawdust additive on the properties of clay. Clay with improved properties such as bulk density, porosity, shrinkage on firing, cold compressive strength refractoriness, thermal shock (spalling resistance) resistance and thermal conductivity would find application in various fields (Kromer and Mörtel 1988).

Experimental Procedure

Materials

Clay samples from deposit in Minna has been studied in this contribution to investigate the chemical compositions, cold crushing strength, refractoriness, thermal conductivity, bulk density, porosity, true density, true volume, bulk volume and linear shrinkage. It was established that the clay sample belongs to the group of alumino-silicate refractories, i.e., fire clay and that the composition is essentially of two basic oxides Al_2O_3 and SiO_2 associated with impurity oxides of TiO_2, Fe_2O_3, MgO, CaO, Na_2O and K_2O about 2-10% when put together. Sawdust from mahogany wood was used as an additive in the experimental procedure (Folaranmi 2009).

Material Preparation

Clay sample as collected from the deposit was soaked in water, and deleterious particles were separated by gravity sedimentation.

Thereafter, the clay sample was sun dried for three days then placed inside the oven and further dried for a period of eight hours at a temperature of 50^{o}C. The dried clay was finally crushed down to smaller sizes, and subsequently ground to finer sizes using the laboratory crusher and the ball mills, respectively. It was sieved and moulded into cylindrical, rectangular and circular shapes depending on the type of test to be carried out on the various clay samples to determine all the properties of the parent clay without additive.

In the second phase of the experiment, ground clay sample was mixed with varying proportions of sawdust (1, 5, 10, 20 and 30%) and was made to pass through a 60 µm mesh.

The new clay preparation was moulded into cylindrical, rectangular, cubical and circular shapes. They were later dried in an oven under a shelf for two weeks and each of them was subjected to various tests for the properties to be determined.

Theoretical Background

The properties of clay sample considered are:

Bulk Density: This is responsible for the overall weight coming upon the foundation of a refractory structure.

Porosity and Permeability: The ability to be impervious to gases and liquids.

Shrinkage on Firing: This is a property of clay material which makes them to undergo least structural changes and disintegration while being heated.

Cold Compressive Strength: This is the ability of clay to bear load.

Refractoriness: This is the resistance of clay to fusion and softening at high working temperatures.

Thermal Shock (Spalling) Resistance: This is the ability of sample to withstand heating and cooling several times before a deep crack appears.

Thermal Conductivity: This is the ability of clay to reduce the rate of heat transfer through it.

Experimental Procedure

Chemical Compositions

This analysis was conducted to express the chemical composition of the clay sample in terms of its oxides. The classical chemical analysis (wet analysis) technique was used in this investigation. The results of the chemical compositions and physical properties of the clay sample without an additive are presented in Tables 1 and 2, respectively.

Bulk Density Porosity

Bulk density and porosity measurements were carried out on convenient cubical shaped test pieces. The specimens were dried in an oven at 110^{o}C for three hours. It was cooled in desiccators and weighed to the nearest 0.01g (weight (D)). The dried specimen was suspended in distil water such that the specimen does not touch the bottom or the sides of the beaker.

The boiling method was used in determining the porosity by boiling the specimen for two hours. While still suspended in water, it was cooled to room temperature and its weight was taken (weight (S)).The specimen was removed from water and the water on the sides was wiped off. The soaked pieces were weighed (weight (W)). From the three weighting readings, the porosity and bulk density were calculated as follows:

$$\text{Apparent Porosity (\%)} = [(W-D)/(W-S)] \times 100, \quad (1)$$

$$\text{Bulk Density (g/cm}^3) = [(D)/(W-S)] \times [D_{water}], \quad (2)$$

where the density of water $D_{water} = (1 \text{ g/cm}^3)$.

The results for the sample are presented in Table 3 and Table 4, respectively.

Shrinkage on Firing

The samples were rammed into moulds of 9.5 x 1.8 x 1.8 cm under an hydraulic press of capacity 350 KN. A slanted line was drawn across the brick and measured before firing (L_1).The specimen was place in a furnace and fired to 1,000^{o}C the line drawn across the piece was measured (L_2).The percentage linear shrinkage was determined using Eq. (3):

Linear shrinkage (%) = $[(L_1 - L_2)/L_1] \times 100$. (3)

The results for this test are presented in Table 5.

Cold Compressive Strength

The clay samples were placed in a sample mould and rammed with Paul Weber hydraulic press of capacity 350 KN. The rammed samples which measured 9.8 x 9.8 x 9.8 cm each and cubical in shape were then removed from the mould and fired to 1,200^{o}C. They were allowed to cool in air before the test was carried out on an *x* test Seidner mechanical strength-testing machine. The actual cold compression strength (*CCS*) was calculated using Eq. (4) (Ryan 1978):

CCS = Crushing Force (KN)/Surface Area (m^2). (4)

The results for this test are presented in Table 6.

Refractoriness

Refractoriness is the maximum temperature a material can withstand after which it will fail (break). The clay samples were placed in the furnace and fired gradually until the samples could not hold their shapes again (Chesti 1986). The temperatures they could withstand are presented in Table 7.

Thermal Shock (Spalling) Resistance.

Samples already fired to 1,200^{o}C were allowed to cool to room temperature and later introduced to an oven set at 450^{o}C. They were soaked in this temperature for 1hour and later removed. The number of cycles of cooling and heating was counted until deep cracks were noticed on the surfaces of the work pieces. The number of cycles before deep cracks were noticed was recorded and presented in Table 8.

Thermal Conductivity

Determination of thermal conductivity of the clay samples was carried out using Lee's disc apparatus. Clay samples were prepared in form of a thin disc of the same diameter of 4.2mm as the copper disc in the apparatus. The thickness of the sample (d), the exposed surface area of the sample (a_S), the area of copper material (a_A), temperature of thermometers T_A and T_B and the Energy supplied (E) in Volts by a 6V battery are used in estimating the thermal conductivity of the material using the relation (Worrall 1982, 1986):

$K = (E_d / 2\pi^2 (T_B - T_A)) \times \{a_S (T_A - T_B)/2 + 2a_A T_A\}$. (5)

The results for this test are presented in Table 9 (Folaranmi 2009).

Conclusion

Investigations have been undertaken to determine the effect of sawdust additive on the properties of clay. Results of the tests conducted are as shown in the Tables 1 – 9 providing additional information about a study which has been initiated earlier by the author (Folaranmi 2009). It was found that some of the properties were improved upon with addition of sawdust while some remained the same; others were affected in the negative direction. With good knowledge of clay properties, clay could be used in various fields.

References

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Table 1. Chemical composition of clay sample.

Oxide	Chemical Composition %
Al_2O_3	19.67
SiO_2	48.24
FeO_3	10.81
MgO	1.33
TiO_2	1.51
CaO	0.55
Na_2O	0.87
K_2O	3.00
Ignition loss	9.74
Others	4.78
Total	100.00

Table 2. Physical properties of clay sample.

Properties	Values
Bulk density (g/m^3)	1.518
Volume fraction of open porosity	0.37
Linear shrinkage on firing (%)	2.47
Thermal conductivity (W/mK)	0.25
Refractoriness (^{o}C) [sintering point refractories]	1430
Thermal shock (spalling) resistance (cycles)	15, crack begins at the 10th cycle
Cold crushing strength (Kg/m^2)	487

Table 3. Variation of bulk density with sawdust.

Sawdust (%)	0	1	5	10	20	30
Bulk Density (g/m^3)	1.518	1.515	1.511	1.507	1.504	1.500

Table 4. Variation of porosity with sawdust.

Sawdust (%)	0	1	5	10	20	30
Porosity	0.37	0.39	0.43	0.48	0.57	0.61

Table 5. Variation of linear shrinkage with sawdust.

Sawdust (%)	0	1	5	10	20	30
Linear Shrinkage (%)	2.47	2.46	2.43	2.40	2.36	2.30

Table 6. Variation of cold crushing strength with sawdust.

Sawdust (%)	0	1	5	10	20	30
CCS (Kg/m^2)	487	455	405	388	344	207

Table 7. Variation of sintering point with sawdust.

Sawdust (%)	0	1	5	10	20	30
Sintering Point (^{O}C)	1430	1430	1430	1430	1430	1430

Table 8. Variation of thermal shock resistance with sawdust.

Sawdust (%)	0	1	5	10	20	30
Thermal Shock Resistance (cycles)	10	10	10	10	10	10

Table 9. Variation of thermal conductivity with sawdust (Folaranmi 2009).

Sawdust (%)	0	1	5	10	20	30
Thermal Conductivity (W/mK)	0.25	0.23	0.19	0.13	0.09	0.06